Using Multiple Sensors with LDC1000

Application Report

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Using Multiple Sensors with LDC100x

ABSTRACT

Inductive sensing is a contactless, magnet-free sensing technology that can measure the position, motion, or composition of a metal or conductive target as well as detect the compression, extension or twist of a spring. TI's LDC100x is the world's first single channel inductance-to-digital converter, enabling inductive sensing by utilizing springs and coils as inductive sensors to deliver better performance, better reliability, and greater flexibility than existing sensing solutions, at a lower system cost.

The LDC100x can be used with a single sensor coil or multiple coils using a signal switch to multiplex the coils. The signal switch can be a relay or a silicon analog switch. In this application note, the different topologies and techniques of sensor multiplexing are discussed, including some examples as well as tradeoffs that need to be made during system design. Note that these topologies and techniques also apply to LDC1041 and LDC1051.

1 Multiplexing Topologies

There are two possible topologies for multiplexing.

1.1 1-to-N Topology

Figure 1 illustrates an example of the 1-to-N topology, where two 1:N switches are required to sample N number of LC sensors. Figure 1 shows a 1-to-2 multiplexer topology.

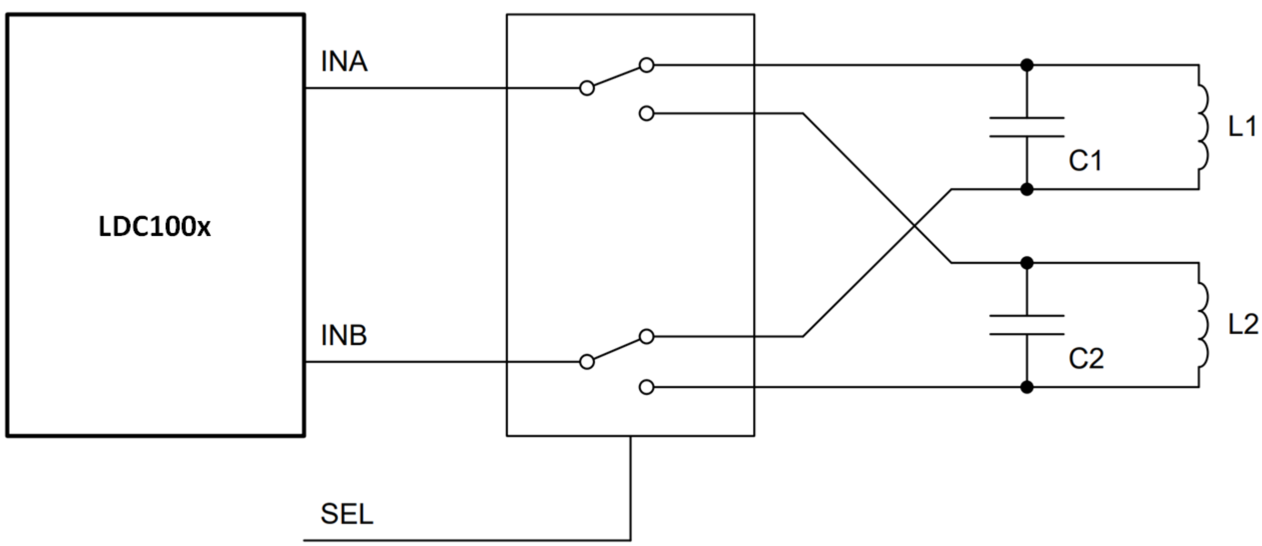

Figure 1. 1-to-2 Multiplexer Topology

The advantages of the 1:N multiplexing is that the LC tank sensors are relatively well isolated from each other electrically, and the performance is predictable if the switch is properly chosen.

1.2 Cross-Bar Topology

In the cross-bar topology, the switches are connected to a matrix of lines, as shown in Figure 2. The advantage of the cross-bar topology is that it requires a fewer number of switches to multiplex a given number of LC tank sensors.

Unlike with the 1:N topology where N switches are required to multiplex N number of LC tank sensors, with the cross-bar topology, N switches can multiplex N^2 sensors.

The disadvantage of the crossbar is that when not selected, the sensors are disconnected only on one side. The side that remains connected to the LDC100x creates a stray capacitance on the active sensor that can lower the resonant frequency of the active sensor as well as pick up any interfering environmental noise.

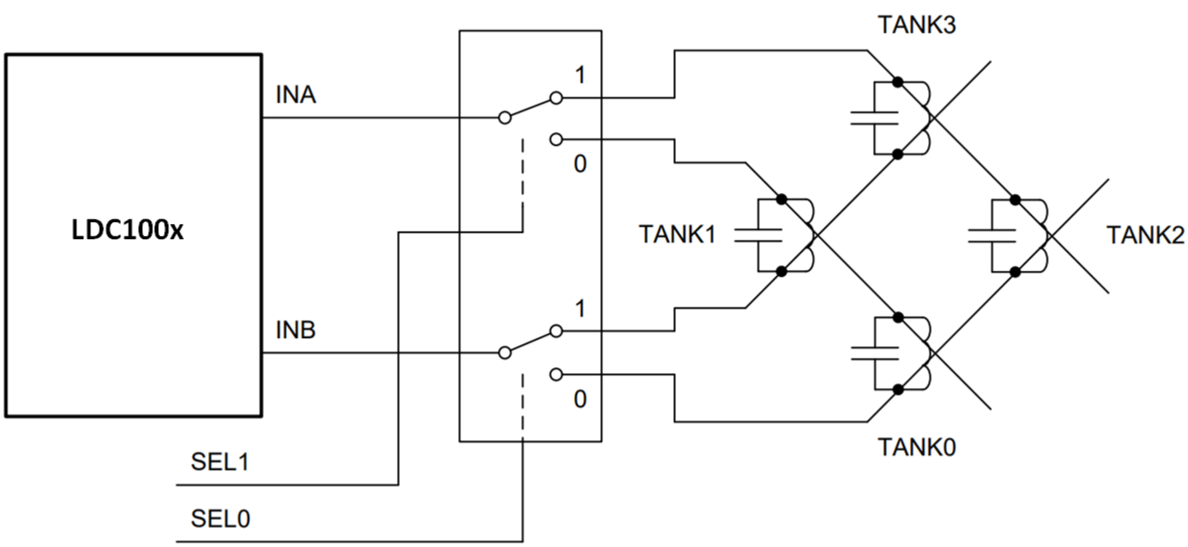

Figure 2. Cross-Bar Topology

2 Using an Analog Switch

Silicon analog switches offer a small footprint area and low cost, and are ideal for LDC100x multiplexing in many applications. However, they are not ideal switches. They have an inherent resistance and capacitance, $R_{(ON)}$ and $C_{(ON)}$, which are the resistance and ground-referred capacitance, respectively, of an analog switch in the “closed” state.

When an LC tank sensor is connected to the LDC100x using an analog switch, the switch adds a capacitance from each of the inputs pins, INA and INB, to ground, as well as a series resistance between the INA and INB pins and the sensor. This can be modeled by a simplified circuit, as shown in Figure 3.

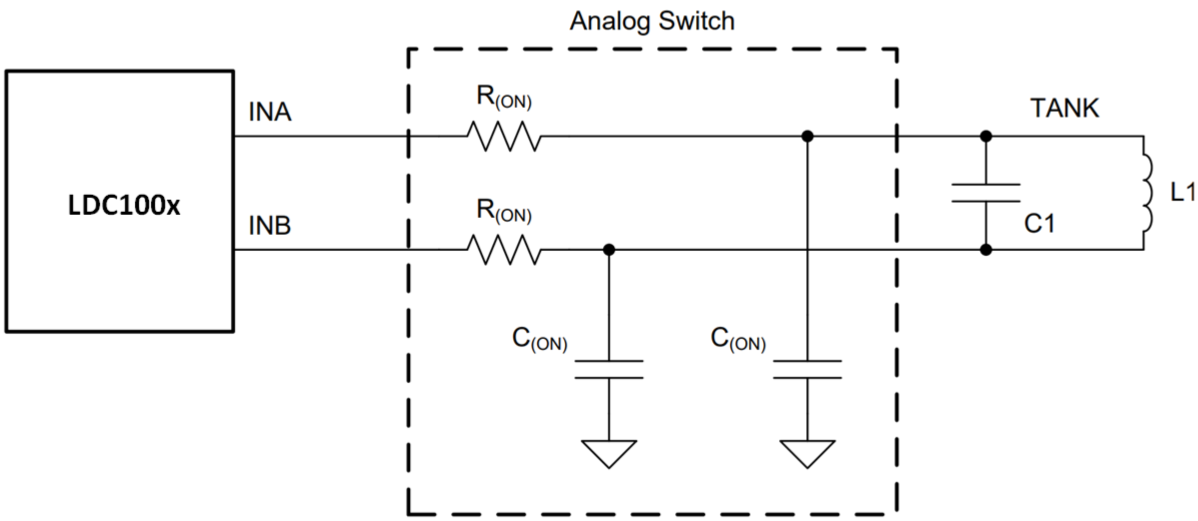

Figure 3. Simplified Model of Analog Switch

3 Selecting an Analog Switch

The analog switches that work well with the LDC100x for the purpose of multiplexing are those with small $C_{(ON)}$. $C_{(ON)}$ is usually a function of temperature, and varies from part to part. To minimize the impact of the parasitic capacitances on the operation of the sensor, C1, as in Figure 3, must be set to a value much larger than $C_{(ON)}$.

The general guideline for selecting $R_{(ON)}$ is that it is less than 50 Ω. A higher value of $R_{(ON)}$ increases the chance of the output stage clipping, causing inaccurate R_P and frequency measurements.

The analog voltage range of the switch must include 0 to 5 V. If the operational range of the analog switch does not support 5 V, then the LDC100x provides the functionality to reduce oscillation amplitude down to 2 V or even 1 V (this is set in the register LDC_Configuration / Amplitude field – bits 4:3 of address 0x04). However, this reduced voltage swing generally comes at the cost of increased measurement noise.

4 Analog Switch Selection Examples

The SN74LV4052A is a low cost, 2-channel, 4:1 analog switch. It can be used with LDC100x to multiplex four coils. Since it has a $C_{(ON)}$ of about 20 pF, a 200 pF or greater value must be used for the sensor capacitor. This analog switch has a typical $R_{(ON)}$ of 25 Ω at room temperature.

The TS3USB30 is a high performance, 2x2:1 analog switch. It has a very low capacitance and resistance, which makes it suitable for more challenging applications where only a very small switch capacitance can be tolerated. TS3USB30's $C_{(ON)}$ is less than 7 pF, ideal for switching high frequency LC sensors. The very low $R_{(ON)}$ of 10 Ω makes it useful in special applications, such as in anti-cross-coupling multiplexing, described later in this application note.

5 Using a Relay

Some relays are very well suited for LDC100x multiplexing. These are usually categorized as RF relays or telecom relays. Their small contact capacitance and low on-resistance makes them better switches than most silicon analog switches, especially for high tank frequency applications. However, relays generally have a larger footprint and may require higher current or voltages for switching. Also, relays may have a longer switching time, typically on the order of several milliseconds. Finally, while relays are very reliable, they are mechanical in nature, and eventually wear out (though several million cycles is common).

The following is a list of examples of RF relays that can be considered:

Part Number	Manufacturer
IM03GR	TE Connectivity
G6K-2F-Y DC3	Omron
AGQ21003	Panasonic Electric Works

6 Mitigating Crosstalk Between Closely Placed Coils

In multiplexed coil applications, if two coils are placed very close to each other, the inactive LC tank sensors can pick up energy from the active LC tank sensor and cause interaction between the two circuits leading to unstable oscillations. To prevent such crosstalk, the rule of thumb is to have the center-to-center distance between the two coils be at least twice the diameter of one coil.

If the application requires that the coils be placed close to each other, the technique illustrated in Figure 4 must be used to separate the frequency of the active and inactive LC tank sensors.

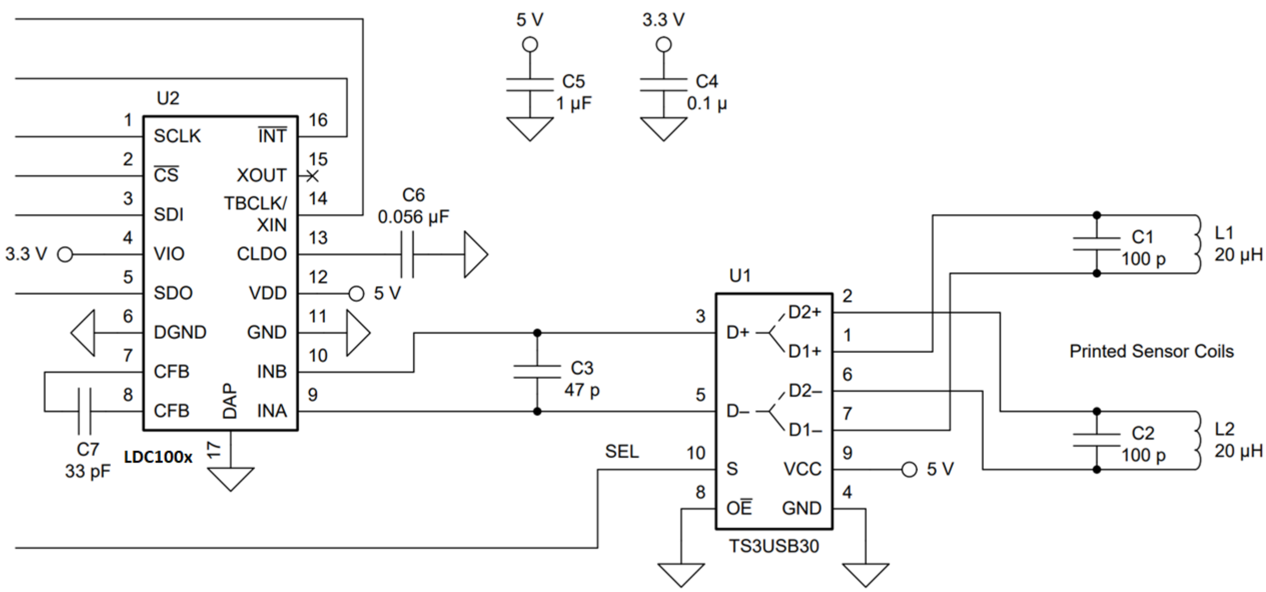

Figure 4. Anti-Crosstalk Scheme

L1 and L2 are the printed sensor coils that are placed close to each other. As can be seen in Figure 4, the active LC tank sensor (the one selected by the multiplexer) is shunted with an additional capacitor C3. In this example, the resonant frequency of the active sensor is 2.9 MHz, while the inactive sensor resonates at 3.5 MHz. Figure 5 shows that a coil with a quality factor, Q, of 20 (typical for printed coils) attenuates by 20 dB the signal from the nearby coil for the two-tank example explained previously. This attenuation is significant enough to eliminate the crosstalk effect.

In this multiplexed-coil implementation, a portion of the LC tank resonant current goes through the switch. This decreases the natural RP of the sensor and lowers the sensitivity. Therefore, the switch used in this implementation must have a lower $R_{(ON)}$ than in other multiplexing topologies.

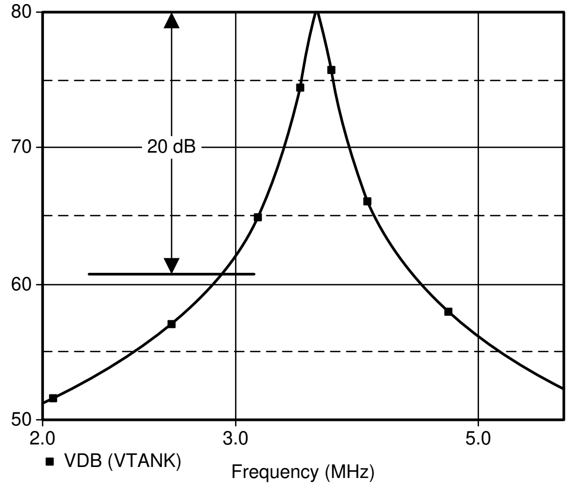

Figure 5. Attenuation in Cross-Coupled Energy

7 Timing Considerations

When the oscillator circuit of the LDC100x is switched from one LC tank sensor to another, the new oscillation takes a certain time to establish. The time needed for the oscillator frequency to settle can be as long as several hundred cycles, and must be experimentally determined.

Figure 6 shows the optimized sample sequence for the applications that can guarantee that the time from MUX select to the completed reading of the SPI register 21 is less than the ODR (output data rate). This includes the time the SPI reading is held by a microprocessor interrupt. In many systems, this requirement can be easily met, and the sequence gives the shortest sampling cycle time.

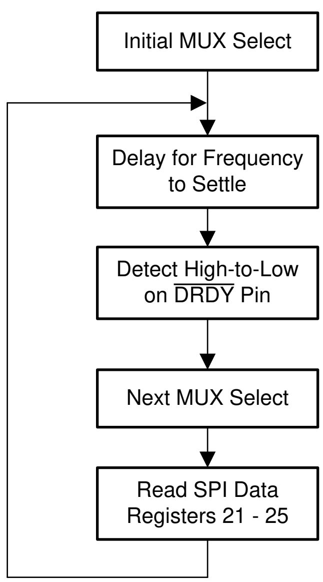

Figure 6. Multiplexing Sequence 1

Figure 7 shows the optimized sample sequence for the applications that cannot guarantee that the time from MUX select to completed reading of the SPI register 21 is less than the ODR (output data rate). Due to the time required to read the SPI register 21, the sampling time may be compromised.

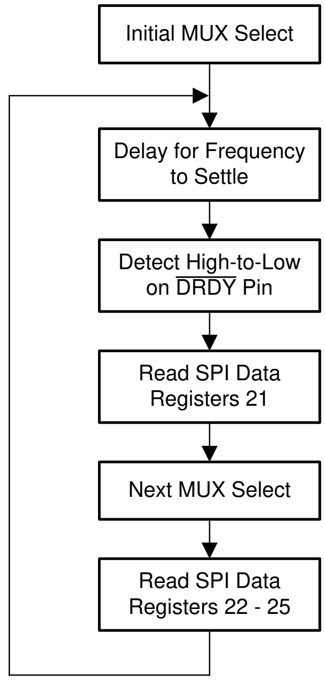

Figure 7. Multiplexing Sequence 2

8 Conclusion

By using signal switches, the LDC100x can be used with multiple sensor coils. The 1:N topology offers an easy design approach and component selection. The Cross-Bar topology can sample more coils with limited switch channels. In high performance applications, relays can be considered. Multiple sensors bring the potential problem of inter-coil interference. By adding an extra capacitor across the INA and INB pins the crosstalk can be effectively eliminated. Optimized sample sequences are introduced.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (March 2015) to A Revision	Page
• Replaced LDC1000 with LDC100x throughout, including within images.	2
• Updated sentence structure for clarity throughout	7

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